US Army Corps of Engineers®

*Navigation Lock and Dam Inspection and Emergency Repairs Workshop*
*ERDC Vicksburg, Mississippi*

# *Methodology for Assessing Concrete Condition for Rehabilitation at LaGrange Lock*

**Anne M. Werner, Ph.D., P.E.**
**Rock Island District**
***18-20 April 2006***

# Methodology for Assessing Concrete Condition for Rehabilitation

US Army Corps of Engineers®

INSPECTION → REPAIR/REHAB? → JUSTIFY FUNDING → FUND?

# Methodology for Assessing Concrete Condition for Rehabilitation

US Army Corps of Engineers®

INSPECTION → REPAIR/REHAB? → JUSTIFY FUNDING → FUND?

# Inspection – LaGrange Lock

US Army Corps of Engineers®

**INSPECTION**

US Army Corps of Engineers®

# Repair/Rehab?

REPAIR/REHAB?

US Army Corps of Engineers®

# Justify Funding - RER

- **Rehabilitation is intended to improve reliability of an existing structure;**
- **Rehabilitation must be economically justified by benefit-cost analysis;**
- **Economic analysis must include probabilistic life-cycle simulation with setbacks for repairs and rehabilitation**

**JUSTIFY FUNDING**

US Army Corp of Engineers®

# Justify Funding - RER

- **EP 1130-2-500 Project Operations - Partners and Support (Work Management Guidance and Procedures) provides guidance for RERs**
- **Allows subjective probability (Expert Elicitation) to calculate probability of unsatisfactory performance**

**JUSTIFY FUNDING**

US Army Corps of Engineers®

# Expert Elicitation

- Should only be used when?
- Who are the experts?
- Model is still required.
  - What to model?
  - How to model?

US Army Corps of Engineers®

# Other Methods for Life Cycle Analysis

- **Methods**
  - **Analytical Models – Freeze/Thaw, AAR, Sulfate Attack, Corrosion**
  - **Condition Indices/Ranking**
- **Issues**
  - **Models**
    - **Large number of variables**
    - **Usable results?**
  - **Condition Indices/Ranking**
    - **Lack probabilistic life cycle analysis**

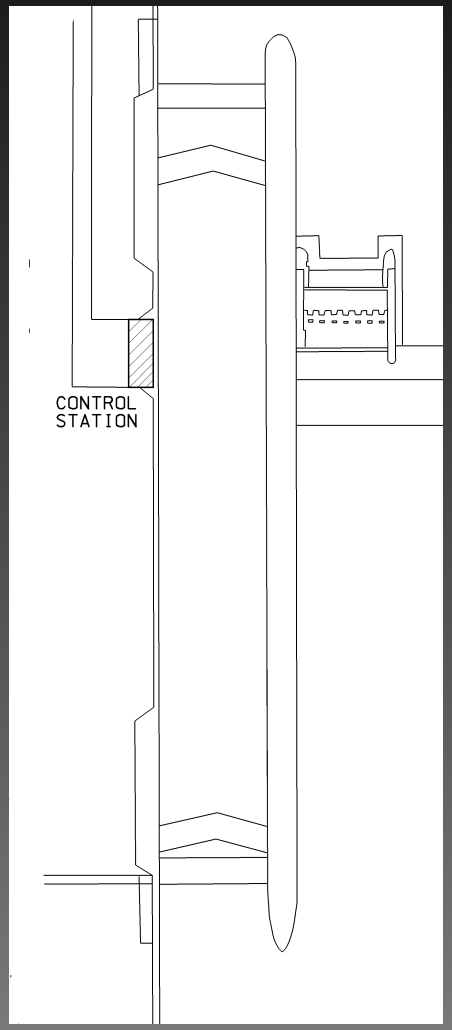
US Army Corps of Engineers

# LaGrange Lock Expert Elicitation Workshop

- LaGrange Lock Concrete Expert Elicitation Workshop (Aug 2004)
- Five experts
- Site visit
- Two day workshop

US Army Corps of Engineers®

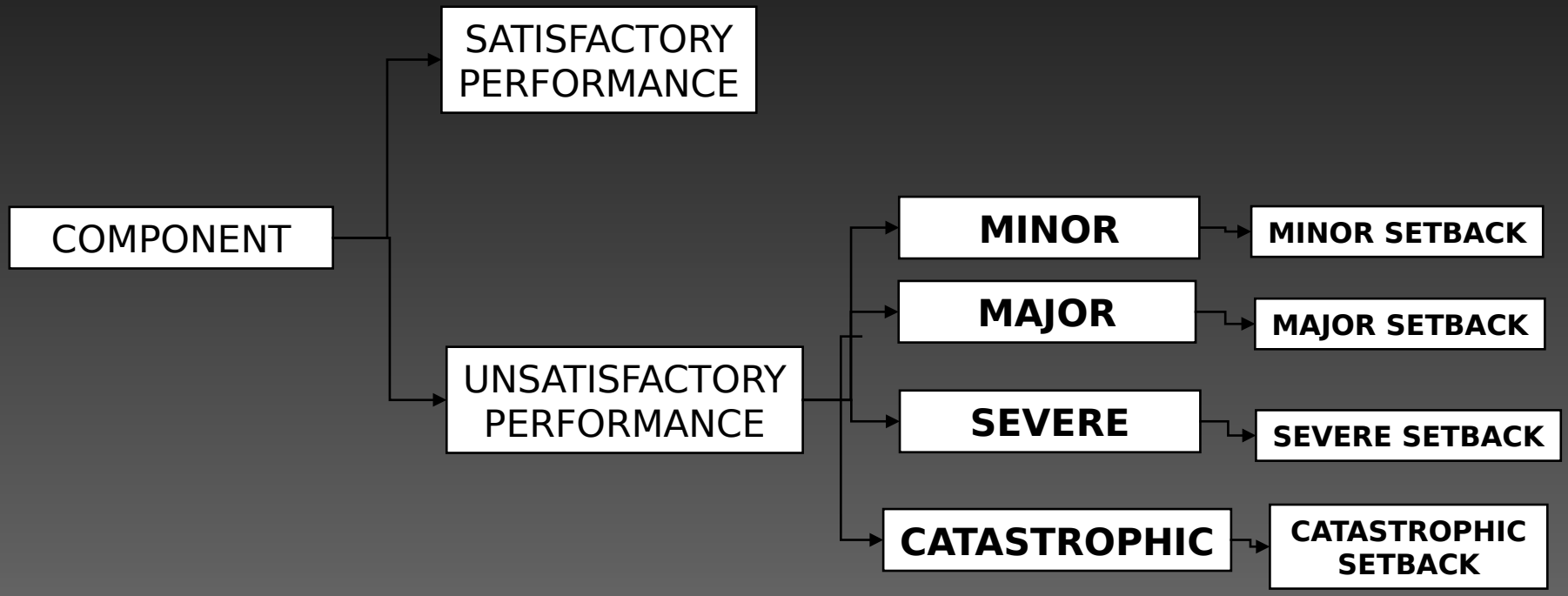
# Elicitation Process




- 4 Components
  - Land Wall Concrete
  - River Wall Concrete
  - Upper Miter Concrete
  - Lower Miter Concrete

US Army Corps of Engineers®

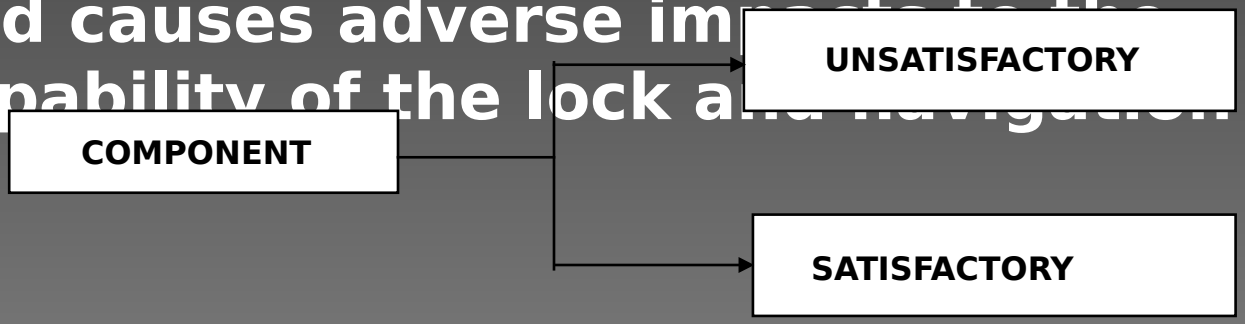
# Elicitation Process



# Elicitation Process

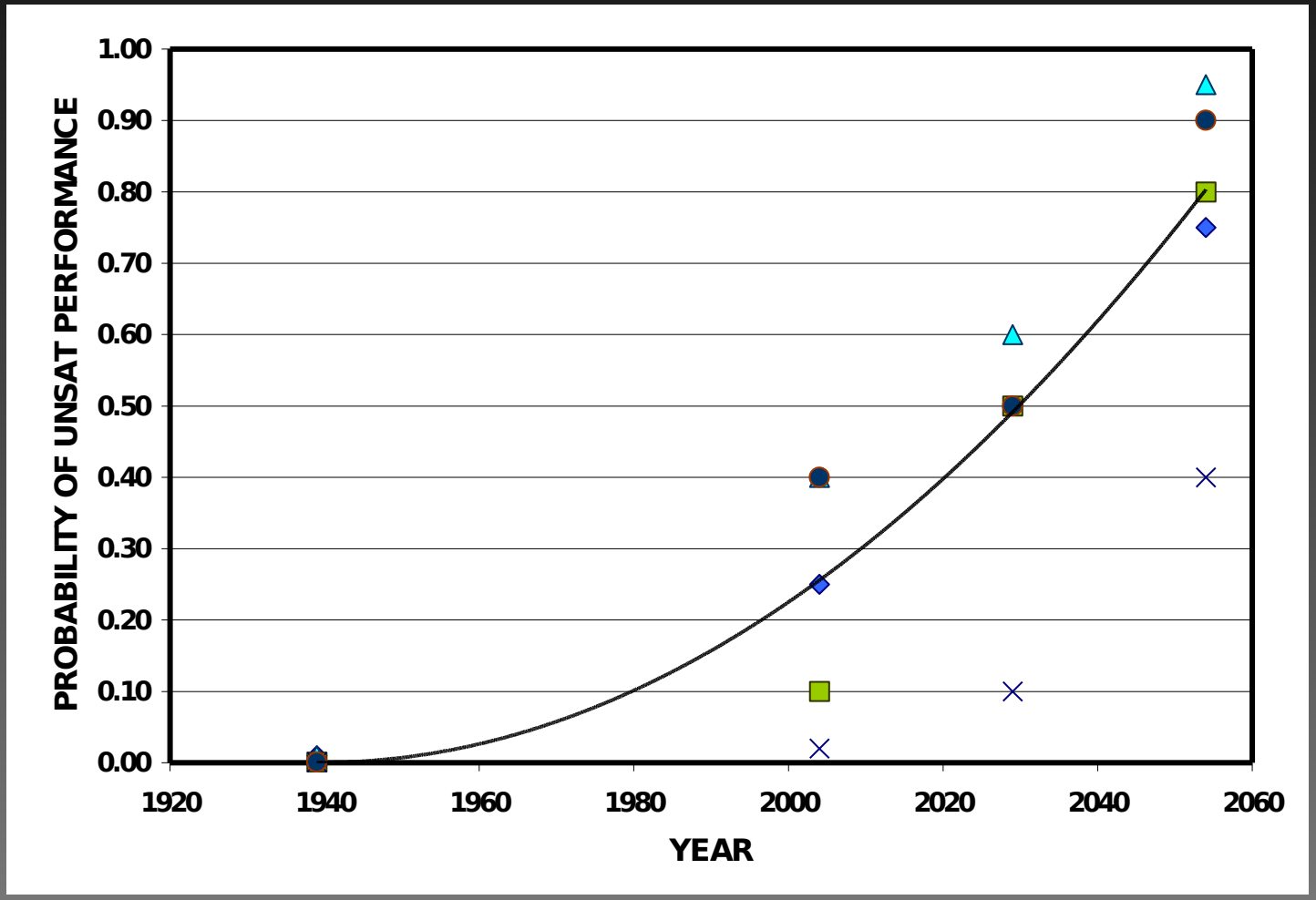
US Army Corps of Engineers®

- **Step 1: Determine the performance probability, P, of an unsatisfactory performance for component**
  - **determined over time - 1939, 2004, 2029, 2054**
  - **unsatisfactory performance means the component has failed to perform properly and causes adverse im… capability of the lock a…**



US Army Corps of Engineers®

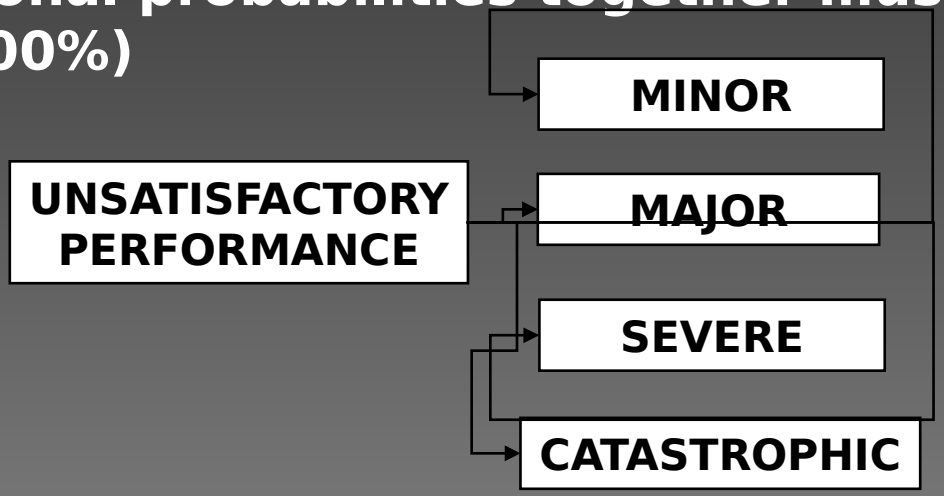
# Elicitation Process



US Army Corps of Engineers®

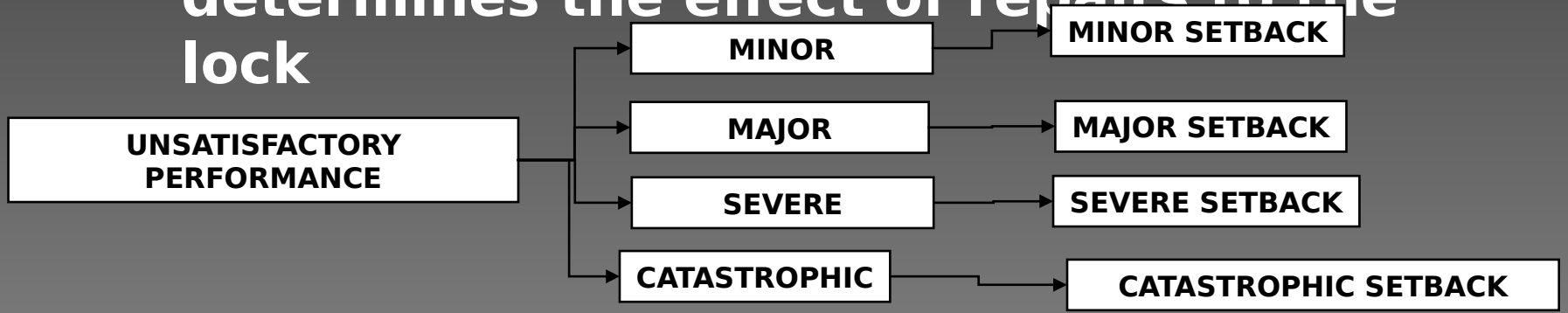
# Elicitation Process

- **Step 2: Given an unsatisfactory performance, determine the conditional probabilities, p1, p2, p3 and p4, of the resulting potential consequences**
  - **minor, major, severe, catastrophic**
  - **conditional probabilities together must add up to 1 (or 100%)**



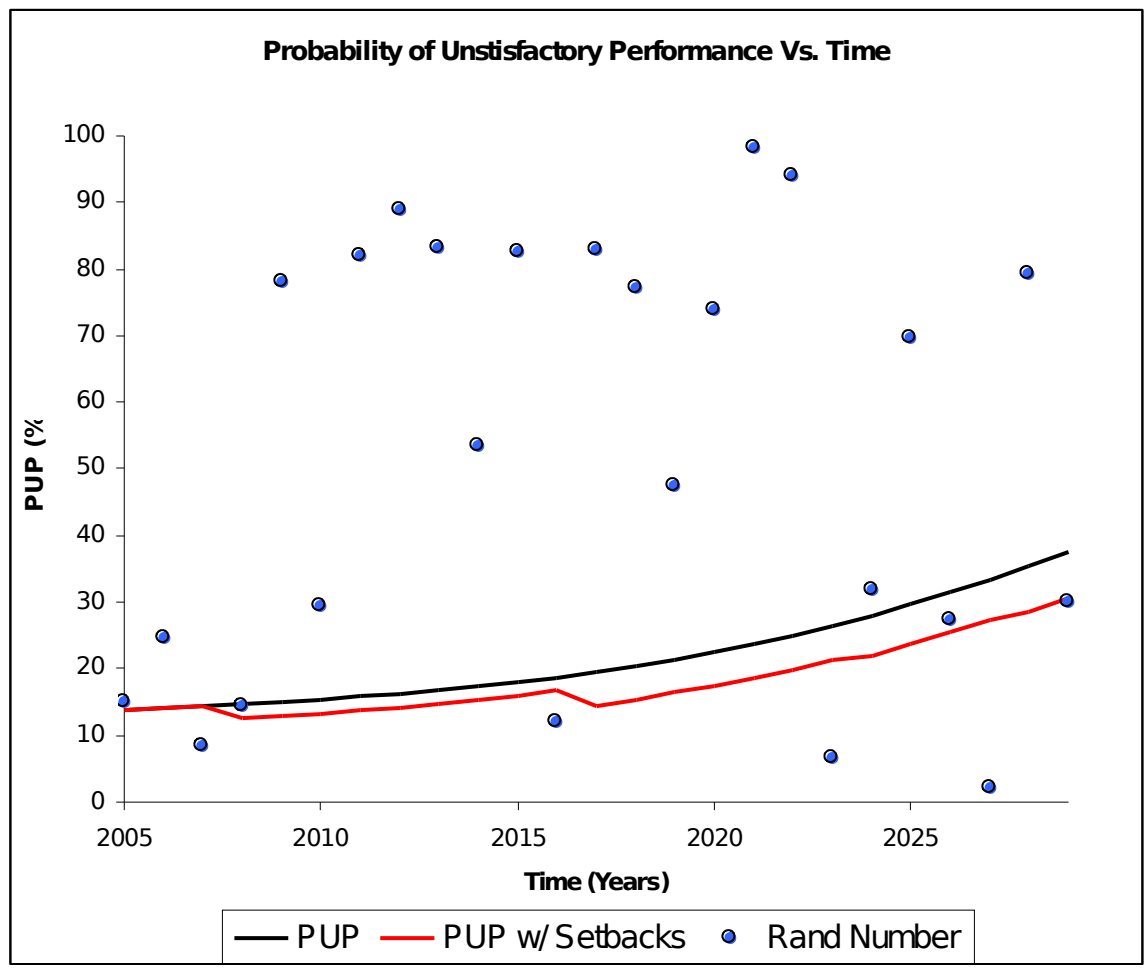
# Elicitation Process

- **Step 3: Given an unsatisfactory performance has occurred and repairs have been made, determine the setback, ΔP, to the future probability of unsatisfactory performance.**
  - **determine for all consequences (minor, major, severe and catastrophic)**
  - **determines the effect of repairs to the lock**



US Army Corps of Engineers®

# Elicitation Results



US Army Corps of Engineers®

# Elicitation Results

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Iterations:** | 10000 | | | | | | | | |
| **Years:** | 25 | | | | | | | | |
| | **Upper Miter** | | **Lower Miter** | | **Land Wall** | | **River Wall** | | **Totals** |
| | Avg 25 years | Avg 1 Year | Avg 25 years | Avg 1 Year | Avg 25 years | Avg 1 Year | Avg 25 years | Avg 1 Year | |
| **Minor:** | 4.639 | 0.186 | 5.491 | 0.220 | 3.928 | 0.157 | 7.094 | 0.284 | |
| **Major:** | 1.506 | 0.060 | 2.095 | 0.084 | 1.272 | 0.051 | 2.832 | 0.113 | |
| **Severe:** | 1.030 | 0.041 | 1.422 | 0.057 | 0.819 | 0.033 | 1.973 | 0.079 | |
| **Catastrophic:** | 0.718 | 0.029 | 0.952 | 0.038 | 0.590 | 0.024 | 1.274 | 0.051 | |
| **Repair Cost:** | | $1,880,335 | | $2,597,189 | | $1,155,558 | | $2,767,888 | $8,400,970 |
| **Closure Time Cost:** | | $17,007,919 | | $23,556,894 | | $14,760,963 | | $35,130,291 | $90,456,068 |

- **Repair costs = $8.4M**
- **Closure time costs = $90.4M**
- **Concrete rehabilitation was recommended by expert panel**
- **New method for determining setbacks**
- **Optional elicitation methods explored**
- **Better understanding of the process**

US Army Corps of Engineers®

# Justify Funding?

- Concrete rehabilitation was recommended by expert panel.
- Annualized cost for concrete rehab - $5.2M
- Annualized benefits - $7.2M
- B/C Ratio = 1.41
- Net Annual Benefits = $2.1M
- RER approved

FUND?

US Army Corps of Engineers®

# Applicability of Expert Elicitation

- **Lock 19**
  - **Closure Cells**
  - **Lockwalls**

Lock 19

# Applicability of Expert Elicitation

US Army Corps of Engineers®

- **Lock and Dam 18**

Dam 18

US Army Corps of Engineers®

# Summary

- **Repair/rehabilitation must be justified by cost/benefit analysis**
- **Expert elicitation provides a method to provide a probabilistic life cycle analysis**
- **Expert elicitation may be an option when other methods are not**
- **Further development of service life models and updated guidance on life cycle analysis would be helpful**

# Questions/Comments?